RESEARCH HIGHLIGHT

Technical Series 05-100

EFFECTS OF THERMOSTAT SETTING ON ENERGY CONSUMPTION

INTRODUCTION

House temperatures are typically set by the occupants to ensure their personal comfort. When occupants are not at home, or are asleep, the house temperature requirements are different. For this reason, many homeowners "set back" the thermostat (reducing the set temperature) during nights as well as during the work day by means of a conventional thermostat or with the aid of a programmable model. This is intended as a simple way to reduce overall household energy consumption during the winter heating season while still ensuring occupant comfort. In summer, a similar strategy can be employed by "setting forward" (increasing the set temperature) during the work day, reducing the load on the air conditioning system during peak hours.

The purpose of this set of experiments was to determine the effects of thermostat setting on household energy performance, and to also examine the overall effect on the house.

METHODOLOGY

The evaluation of thermostat setback and set forward strategies was carried out at the Canadian Centre for Housing Technology (CCHT)[1] in Ottawa in 2003. The CCHT Twin-House Research facility, with its multiple sensors and continuous data recording, is ideal for this type of experiment.

To determine the effect of a given technology, the CCHT houses are first benchmarked under identical conditions, and then a single element is changed in the "Test" house. In benchmark conditions, thermostats were set to 22°C (71.6°F), a mid-efficiency gas furnace provides the heat and its fan provided low-and high-speed continuous circulation during heating and cooling seasons. A high efficiency 12 SEER AC units provided cooling. A total of 28 winter and 27 summer benchmarking days were collected.

The Test House was set to the following winter setback settings (from 22°C):

- 18°C (64.4°F) night setback (11 p.m.-6 a.m.) for 13 days
- 18°C (64.4°F) night and day setback (11 p.m.-6 a.m., 9 a.m.-4 p.m.) for 16 days
- 16°C (60.8°F) night and day setback (11 p.m.-6 a.m., 9 a.m.-4 p.m.) for seven days

Two summer thermostat settings were examined:

- 24°C (75.2°F) higher temperature setting, 24 hours a day for 14 days
- 25°C (77°F) day set forward (9 a.m.-4 p.m.) for 20 days

Data collected throughout the experiments and benchmarking included: AC electrical consumption, furnace gas and electricity consumption, furnace-on time in heating and cooling mode, drywall surface temperatures, window surface temperatures, house temperature and humidity, and solar radiation.

FINDINGS

Energy savings

The winter experiments demonstrated that as the setback temperature is decreased, energy savings increase. Higher savings are achieved (as a percentage) on colder days with longer furnace-on times. The greatest savings occurred on the coldest–cloudiest day (minimum -26.2°C [-15.16°F] to maximum -15.4°C [4.28°F] outdoor temperature) of the 16°C (60.8°F) night and day setback.

The setback reduced furnace-on time by 228 minutes, saving 163 MJ of gas and 0.98 kWh of electricity over the benchmark condition. It was also noted that in warmer conditions; for example, outdoor temperatures above 0°C (32°F), the net benefits were not detectable.

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[1] The Canadian Centre for Housing Technology is jointly operated by the National Research Council, Natural Resources Canada and Canada Mortgage and Housing Corporation. This research and demonstration facility features two highly instrumented, identical R-2000 homes with simulated occupancy to evaluate the whole-house performance of new technologies in side-by-side testing.
For more information about the CCHT facilities, please visit http://www.ccht-cctr.gc.ca.

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These R-2000 houses don't have time to cool down significantly overnight to show an appreciable saving.

During the summer thermostat set forward, electrical savings increased with higher outdoor temperature and larger solar gains. The highest savings occurred on the hottest day, when the minimum outdoor temperature was 20.4°C (68.72°F) and the maximum 30.2°C (86.36°F). The set forward resulted in a reduced on-time of 236 minutes; 6.39 kWh savings in AC compressor consumption, and 1.18 kWh savings in furnace fan consumption.

The higher temperature setting produced consistently high savings independent of temperature or solar radiation, resulting in an estimated 23 per cent savings in AC and furnace electrical consumption for the entire cooling season.

The predicted seasonal savings, shown in Tables 1, 2 and 3, were calculated using the experimental results of this project combined with one year of monitored data for the CCHT reference house and using a method described in the CCHT report *Analysis of Annual Energy Consumption for the CCHT Research Houses.*

Effects of solar radiation

The amount of sun each day had a major effect on both daytime setback and set forward experiments. Thermostat setback proved most effective on cloudy days. In winter, the added energy from solar radiation sometimes kept the Test House from dropping to the setback temperature, reducing the savings from daytime setback.

In summer, the effect was opposite and even more prominent. The sunnier the day (higher solar radiation), the higher the savings from thermostat set forward. For the sunny days the experiment obtained 13 per cent electrical savings from set forward, as opposed to only 2.9 per cent from all cloudy days (see Table 3).

Recovery time

Recovery time is a measure of the time taken for the house air temperature to return to its original setting. Recovery times from thermostat setback were all below two hours—on most occasions taking less than one hour to recover. The lower the temperature the house is allowed to reach (that is, the lower the setback temperature) the longer the recovery time.

Recovery time from summer thermostat set forward were much longer—up to seven hours on the hottest days—the same length of time as the set forward itself. This long recovery time would be expected to affect occupant comfort in the evenings.

Table 1-Predicted winter gas savings from thermostat setback in the CCHT Test House

	22°C benchmark	18°C night setback	18°C night and day setback	16°C night and day setback
Furnace gas consumption (MJ/yr)	66,131	61,854	59,231	57,241
Savings from benchmark (per cent)	---	6.5	10	13

Table 2-Predicted winter electrical savings from thermostat setback in the CCHT Test House

	22°C benchmark	18°C night setback	18°C night and day setback	16°C night and day setback
Winter furnace fan electrical consumption (kWh/yr)	2,314	2,295	2,270	2,261
Savings from benchmark (per cent)	---	0.8	1.9	2.3

Table 3-Predicted summer electrical savings from thermostat setting in the CCHT Test House

	22°C benchmark	24°C 24 hours	25°C 9:00 AM to 4:00 PM—all	25°C 9:00 AM to 4:00 PM—cloudy	25°C 9:00 AM to 4:00 PM—sunny
Summer circ. fan and AC electrical consumption (kWh)	3,104	2,381	2,771	3,015	2,694
Savings from benchmark (per cent)	---	23.3	10.7	2.9	13.2

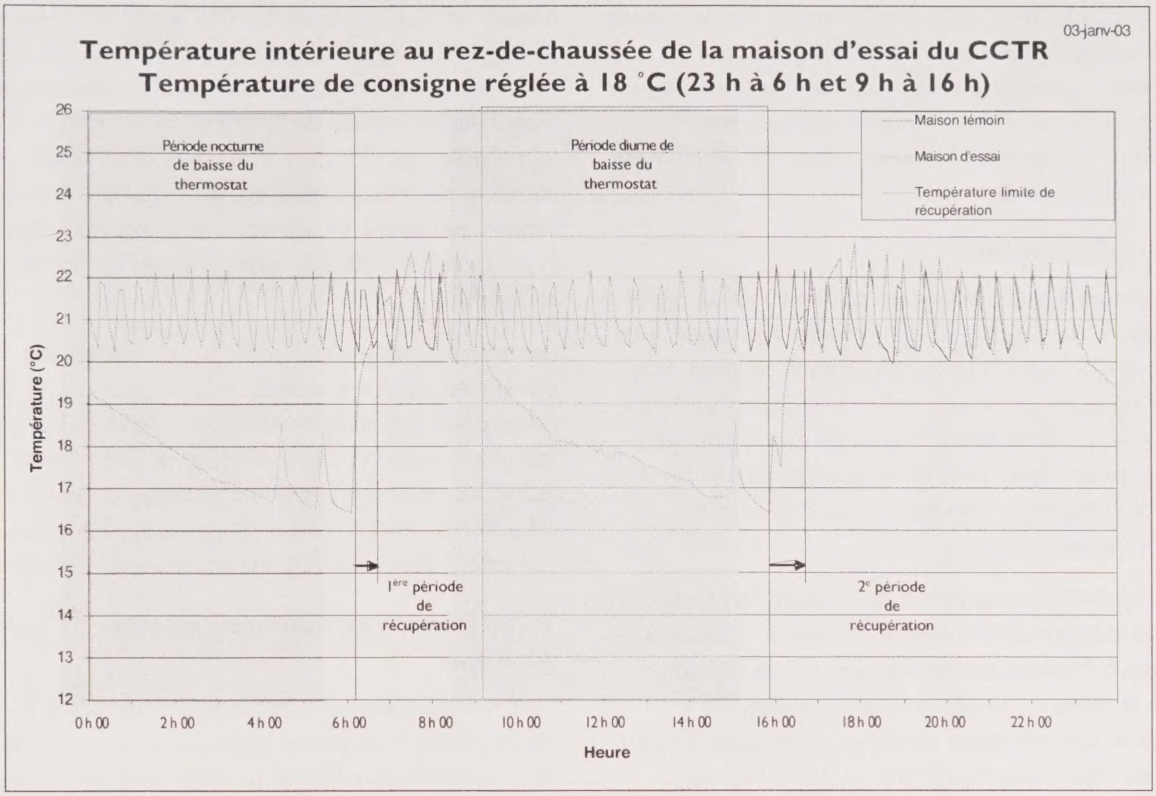

Figure 1 - Exemple de période de récupération de la température de l'air résultant d'une baisse du thermostat à 18 °C, tant la nuit que le jour, le 3 janvier 2003 —Températures minimales et maximales extérieures de -8,5 °C (16,7 °F) et de -4,7 °C (23,54 °F) respectivement

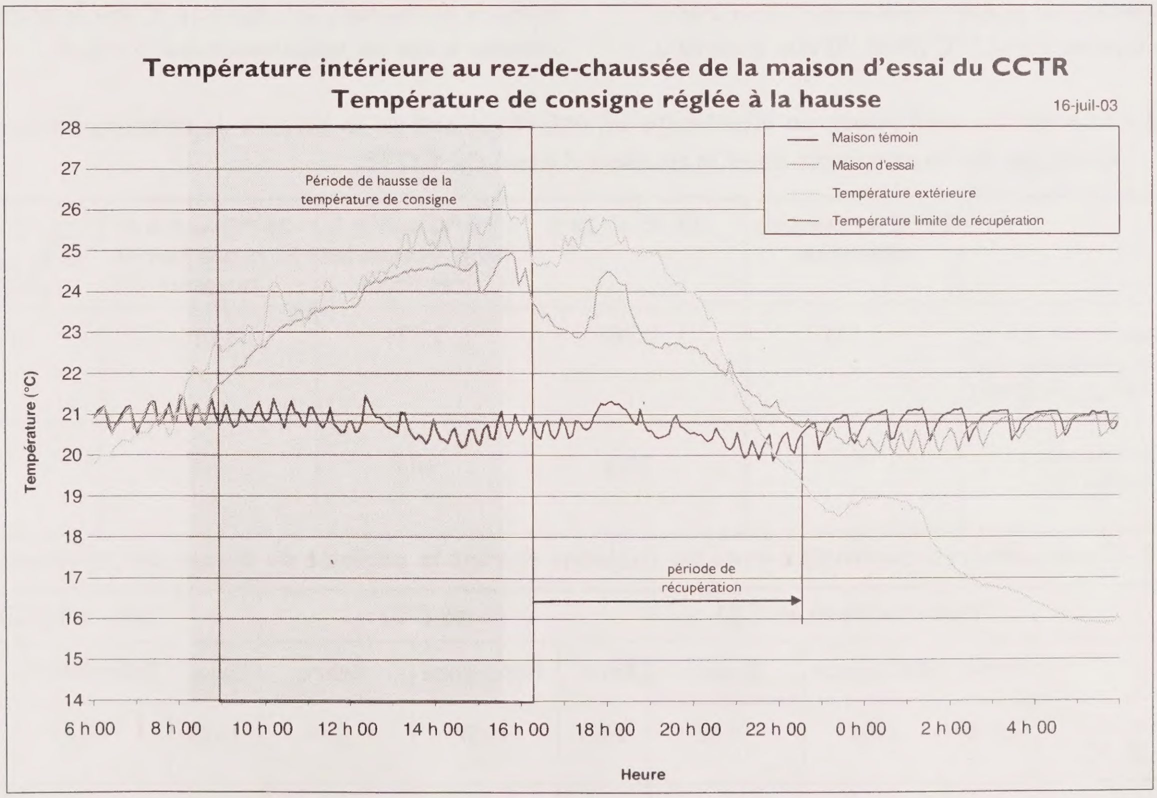

Figure 2 - Exemple de graphique montrant la période de récupération résultant d'une hausse de la température de consigne

En été, l'effet est contraire et même plus prononcé. Plus la journée était ensoleillée (rayonnement solaire plus élevé), plus les économies étaient importantes. Lors de journées ensoleillées, on a réalisé des économies de 13 % en consommation électrique, comparativement à seulement 2,9 % pour l'ensemble des journées nuageuses (voir le tableau 3).

Temps de récupération

Le temps de récupération constitue une mesure du temps requis pour que la température dans la maison revienne à la température de consigne originale. Les temps de récupération résultant de la baisse du thermostat ont tous été inférieurs à 2 heures, et dans la plupart des cas, moins d'une heure. Plus on permet à la maison d'atteindre une basse température (c'est-à-dire plus on baisse la température de consigne du thermostat), plus la période de récupération est longue.

Les temps de récupération résultant de la stratégie de hausse de la température de consigne du thermostat se sont avérés beaucoup plus longs : jusqu'à 7 heures pendant les jours les plus chauds, autrement dit, le même temps que la durée du réglage de la hausse elle-même. On estime que ces temps de récupération plus longs auront des répercussions négatives sur le confort des occupants en soirée.

Température de surface en hiver

Pendant les essais de baisse de la température de consigne du thermostat, la surface des plaques de plâtre au 1[er] et au 2[e] étage est demeurée supérieure à 12,7 °C (54,86 °F) dans le cas de la baisse à 16 °C et au-dessus de 17,8 °C (64,04 °F) pour la baisse à 18 °C. À l'endroit où on a enregistré la température de surface la plus froide sur les plaques de plâtre, de la condensation se produirait à une humidité relative de 55 % à 22 °C (71,6 °F). Il faut noter que les températures de surface des plaques de plâtre ont été mesurées au centre de la cavité isolée du mur, et que les températures seraient plus basses sur les éléments d'ossature, comme la sablière et les angles, ou à d'autres endroits où les performances thermiques sont réduites.

Les températures les plus basses sur les fenêtres ont été enregistrées sur les dormants : aussi bas que -2,6 °C (27,32 °F), même durant les essais de référence. Il faut s'attendre à de la condensation ou à la formation de givre sur le dormant, à moins que le taux d'humidité relative soit maintenu en deçà de 19 % à 22 °C (71,6 °F). Puisque les maisons n'ont pas été humidifiées durant la période d'essai en hiver, aucune condensation n'a été observée.

Température et humidité relative de l'air intérieur

Les effets découlant de la baisse de la température de consigne du thermostat en hiver étaient les plus notables au rez-de-chaussée, car la température minimale suivait de près celle du thermostat. En dépit du fait que la température dans le sous-sol ait atteint des valeurs inférieures à celles du rez-de-chaussée au cours de l'étude, les températures minimales dans la maison d'essai et dans la maison témoin affichaient une différence de moins de 2 °C, même lorsque le thermostat a été réglé à 16 °C. Voir le tableau 4 pour consulter la liste des températures dans la maison.

Tableau 3 - Économies anticipées en électricité en été résultant de la hausse de la température de consigne du thermostat dans la maison d'essai du CCTR

	22 °C — point de référence	24 °C — 24 h	25 °C — 9 h à 16 h — tous les résultats	25 °C — 9 h à 16 h, par temps nuageux	25 °C — 9 h à 16 h, par temps ensoleillé
Consommation électrique du ventilateur du générateur de chaleur et du climatiseur (kWh)	3 104	2 381	2 771	3 015	2 694
Économies par rapport au point de référence (%)	---	23,3	10,7	2,9	13,2

Tableau 4 - Températures minimales dans les maisons durant la période de baisse des thermostats

	Rez-de-chaussée (°C)			2[e] étage (°C)			Sous-sol (°C)		
	Essai	Référence	Écart	Essai	Référence	Écart	Essai	Référence	Écart
Température de référence : 22 °C	21,69	21,27	0,42	20,01	19,57	0,44	16,68	17,02	- 0,34
Baisse à 18 °C	18,06	21,1	- 3,04	16,93	19,79	- 2,86	14,26	15,72	- 1,46
Baisse à 16 °C	15,81	21,15	- 5,34	14,77	19,41	- 4,64	13,67	15,32	- 1,65

CONCLUSIONS AND IMPLICATIONS FOR THE HOUSING INDUSTRY

The experiments showed that thermostat setback has significant potential as an effective and inexpensive energy-saving method, even in an energy-efficient house. Savings from thermostat setback and house temperatures will be different for all types of homes and mechanical setups. For this reason, it should be noted that these findings are valid for the CCHT Twin Houses and an energy model should be used when projecting the results to other situations.

The lengthy recovery period from the summer set forward highlights the need for a different approach to thermostat setting during the cooling season. Large savings were produced by simply increasing the thermostat setpoint. However, when it comes to setting this setpoint in the home, occupant comfort will likely be the determining factor.

A full report on this project is available from the Canadian Centre for Housing Technology.

The Canadian Centre for Housing Technology

Canada Mortgage and Housing Corporation (CMHC), The National Research Council (NRC) and Natural Resources Canada (NRCan) jointly operate the Canadian Centre for Housing Technology (CCHT).

CCHT is a unique research, testing and demonstration resource for innovative technology in housing. CCHT's mission is to accelerate the development of new housing technologies and their acceptance in the marketplace.

CCHT operates a Twin-House Research Facility, which offers an intensively monitored, real-world environment. Each of the two identical, two-storey houses has a full basement. The houses, 223 m^2 (2,400 sq. ft.) each, are built to R-2000 standards.

For more information about the CCHT Twin-House Research Facility and other CCHT capabilities, visit http://www.ccht-cctr.gc.ca.

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